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Shoreline Pilling Foundation Design in Karst Formation, Port Sudan, Red Sea, Sudan

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ABSTRACT : Coastal reef limestone almost covered the Sudan's coastal plain. The limestone in coral reefs shows the effect of chemical solution forming channels and caverns when submerged by Sea water. Site investigation in Dama Dama including drilling standard penetration test, geophysical survey, soils and water sampling, geotechnical properties of soils and geotechnical map had been done in this work. The overall objective of this study is to Pilling foundation designation on shoreline in karst formation for heavy constructions. Many tests have been done to confirm load predictions and account for design uncertainly includes safety factor, Settlement, Load test, Skin friction and Load Capacity. The best layer which pile should rest is coral reef limestone of weathering grade III. Therefore, it is strongly recommended to use pilling foundation in the intertidal zone and highly safety measures must be consider in building in lightly hazardous zones.

***KEYWORD:** Dama Dama, Coastal reef, backshore and design*

1. INTRODUCTION

Coastal reef limestone almost covered the Sudan's coastal plain. The stratigraphy and subsurface weathering grade investigation for foundation suitable of port-Sudan had been done by (al-Imam, et. al., 2013), generally, limestone which originated in coral reefs shows the effect of chemical solution forming channels and caverns when submerged by Sea water. The presences of the fine-grained carbonate minerals together with macro-fossils indicate that the coastal plain has unreliable geotechnical properties (Al-Imam, et. al., 2013).

Although, the mechanical parameters values give an encouragement for engineering, all foundation in the Sudanese coastal plain and/or which like must be pilling design with taken case in soil geotechnical profile (Al-Imam et. al., 2013b).

1. Location and site investigation

Dama Dama is located about 7.0 Km southern port-Sudan (**Fig .1**) site investigation including drilling standard penetration test (SPT), geophysical survey, soils and water sampling, geotechnical properties of soils (physical and mechanical) and finally geotechnical map had been done by professional scientist team.

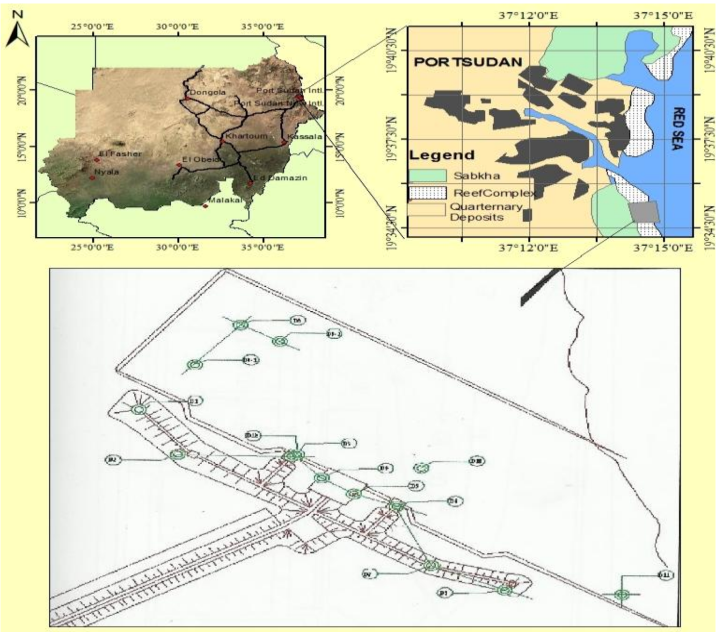

Fig. 1: Location map of the study area

2. OBJECTIVE

Pilling foundation designation on shoreline in karst formation for heavy constructions.

3. TECHNIQUE AND METHOD

The karst formation including calcareous soil vary significantly in composition and engineering behavior between nearly locations and are difficult to extrapolating result. In this formation and soil like, piles used backshore, near-shore and offshore are usually open- ended pipe piles can be easily applied offer a good strength the weight ratio, minimize soil disturbance during installation and minimize driving resistance (Mc Carel and Beard R. M., 1984). In this study, a pile cavity is drilled to the required penetration (depth) and then a pile inserted and grouting to form a composite pile. These techniques have been used for backshore and shore line zone in addition insert pile technique can be used.

Many tests should be done to confirm load predictions and account for design uncertainly. Agrwal, et. al., (1977) recommended design parameters based on carbonate content, and (Datta et. al., 1980) recommended coefficient of lateral pressure for calculating skin friction (Agrwal et. al., 1977). However, the full-scale pile-load test is the best method for site-specific parameters into consideration and has been used in this study.

3.1. Designation

Safety factor: the commonly apply safety factor for an end–bearing and overall load following the expression:

$Q_{ult}/2$ (for the pile)

and

Q_{ult} (for the shalt) + Q_{ult} (for the base)

Tomlinsou (1986) decided a safety factor of 2.5 on the ultimate load as an average of base resistance and skin friction where others take the average 3.

Settlement:

The general equation of settlement is:

$P_i = Q_n.B\ \{(1\text{-}m^2)/E_d)\}\ I_p,$

Where:

B= width; E_d=deformation modulus; m= Poisson's ratio

Q_n= net foundation pressure; I_p= influence factor.

Blows (1984) predicate (m) for coarse and fine sands as 0.15 and 0.25 respectively and 0.35 for silt. Calcareous soils have been suggested in this study by 0.20 and the above equation for modularity becomes:

$P_i=0.6\ q.B/E_d$

Then the settlement of the pile base can be calculated.

Load test:

The total test load should be 20% of the proposed design load and 25 % increments applied to the pile (Liucheng, 1981). In case of excessive settlement it should be to reduce the applied load on the pile or decrease the load on the base or to penetrate the pile deeper.

Skin friction:

Pile in calcareous soils carry high load it time is allowed after driving. The unit negative skin friction force at any depth can be calculated from Meyerhole's equation:

$f_{sneg} = \beta P_0$

Where

P_0 = is the effective overburden pressure and β is a reduction factor in rang of 0.3- 0.1 depend on the pile length. Johannsse and Abjerrum (1965) reported that, the negative skin friction is proportional to the effective

overburden pressure in soils surrounding the pile. The constant of proportionality is called Beta (β) coefficient. It is a function of the earth messure coefficient in the soil (R_s) and the ratio of the all friction: $MK_s \tan Ø/\tan Ø$ (Bozozuk, 1974). Thus, the negative skin friction (q_n):

$F_{sneg}=q_n= BP_o=MK_s \tan Ø$

Where, $M=P_o$

Load Capacity:

In calcareous soils the skin friction increasing with depth up to the critical depth, beyond which it remain almost constant. The design of pile requires determination of the proportion of the load transferred to the soil by adhesion and friction between the pile and the soil, that transferred be end bearing (Ferritto and Nakamoto, 1984).

The adhesion factor is a function in the equation of pull out capacity pile:

$T_{ult} = C_A 2\pi RL$

Where: C_A = adhesion value, R = diameter of pile and L = length of pile

Comparing with the pile capacity and effective stress and soil condition in marine environment, the value of (T_{ult}) is very small and can be neglected.

3.2. Applications

Shoreline pile design:

According to boreholes logging, weathering grade (Al-Imam et. al., 2013 a), geophysical survey (Kheiralla, K. M., et. al., 2013) and geotechnical properties (Al-Imam et. al., 2013a), the pile should be rest on coral reef limestone which characterized by weathering grade III below 24 m depth. The specifications of pile are:

Diameter (D) = 1.0 m, Length (L) = 30 m and the material is concrete.

Soil profile:

Figure (2) shows angle of internal friction Ø, field density (wet density Υ_{wet}) overburden pressure and critical depth (Z_c)

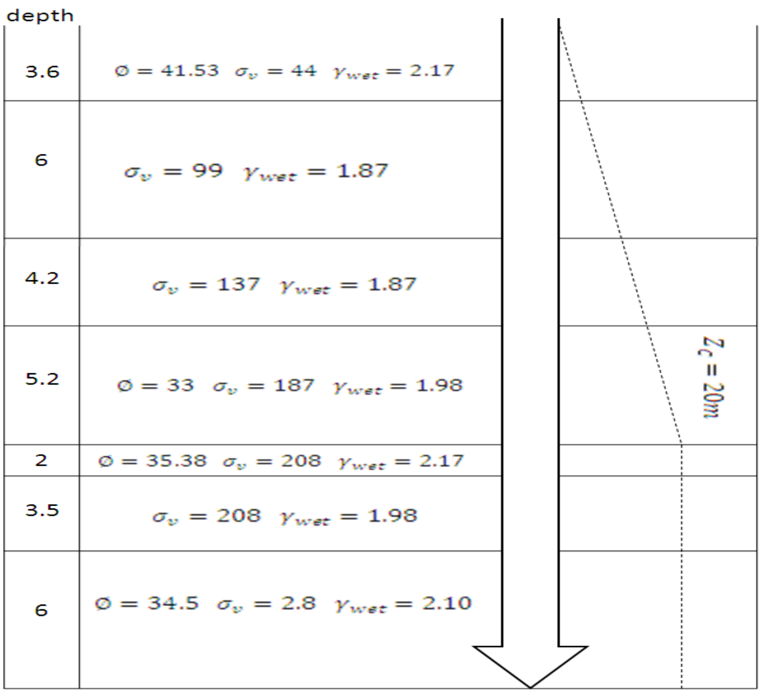

Fig. 2: Onshore soil profile, Dama Dama

3.3. Calculation

<u>Total bearing capacity:</u>

The general equation is:

$$P_u \int_0^L C\left[(\delta_v k_s tan\emptyset) + A_b\,\delta_v N_q - w\right]$$

It is a combination of skin friction plus the base bearing capacity.

Where:

C= perimeter of pile of pile,

δ_v= overburding pressure,

k_s= coefficient of skin friction,

$k_s\,tan\emptyset$= skin friction,

A_b= base area of pile,

N_q= ultimate bearing capacity factor,

w= weight of pile (very small weight comparing with skin friction and base bearing capacity, it can be neglected)

<u>Skin Friction:</u>

It is calculated for each layer according to the angle of internal friction ($\emptyset$). In sand $\emptyset = \emptyset^{'}$ but in clay$\emptyset^{'} = \emptyset^{'} - 3$. For soil profile the skin friction had been determined by using the standard carves designed by Tomlinson (1986) (Fig. 3).

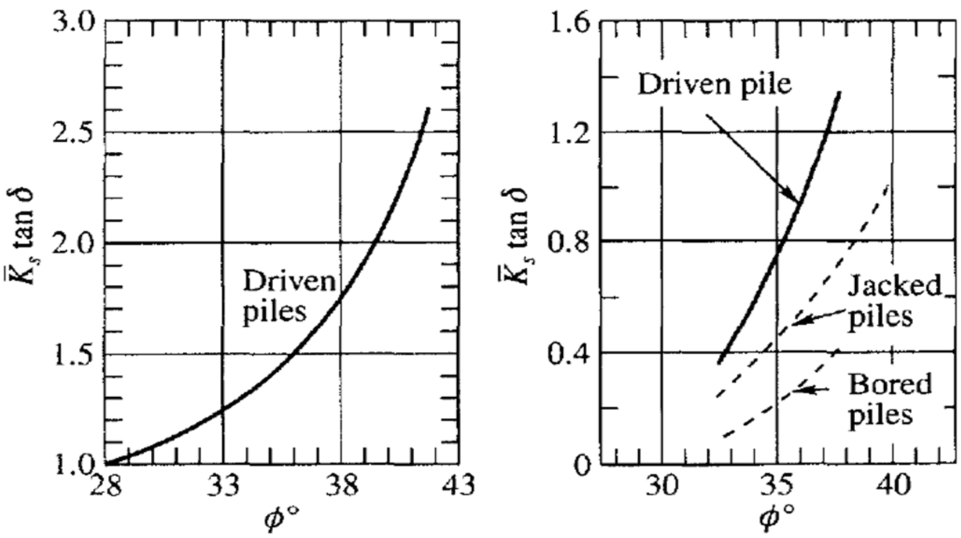

Fig. 3: Values of Z_c/dK_s tan Ø' for piles in sand (after Tomlinson, 1987)

The results are:

i. 00-3.6 = Ks tan Ø =1.0
ii. 9.6-3.6 = SPT<6 cannot be calculated.
iii. 13.8-9.6 = SPT<6 cannot be calculated.
iv. 19.0-13.8 = Ks tan Ø =0.06
v. 21.0-19.0 = Ks tan Ø =0.20
vi. 24.5-21.0 = SPT<6 cannot be calculated.
vii. 30.5-24.5 = Ks tan Ø =0.18

The total skin friction for each layer is:

Z.Ks tan Ø. δ_v

Then, the skin friction for each layer is:

i. 158.4
ii. -
iii. -
iv. 58.344
v. 83.2
vi. -
vii. 224.64

The total skin friction for all layers is the sum of skin friction of every layer multiply by perimeter (C) of the pile:

523.584x1x3.14=1644.05 KN/m^2

Negative skin friction determined by Meyerho's equation:

F_{sneg}= BP_o= 0.2x1644.05=328.8 KN/m^2

The total is: 1644.05-328.8=1315.25

<u>Base bearing capacity:</u>

The second part of the general equation is represented the base bearing capacity of pile

$[A_b \delta_v N_q]$

Where,

$A_b = {\pi D^2}/{4}$

N_q= coefficient for deep foundation (obtained from the standard curve designed by (Pierre Le Tirant, 1979) (Fig. 4).

δ_v= overburden pressure equal 208

Hence: P_b = (3.14/4)x1x208.44=7184.32 KN/m^2

The total bearing capacity is:

= 8499.57/3 safety factor

= 2833.19 KN/m^2

= 283.19 KP_a/m^2

= 28.319Ton/m^2

The ${\pi D^2}/{4}$ = 28.319 = 22.23 ton

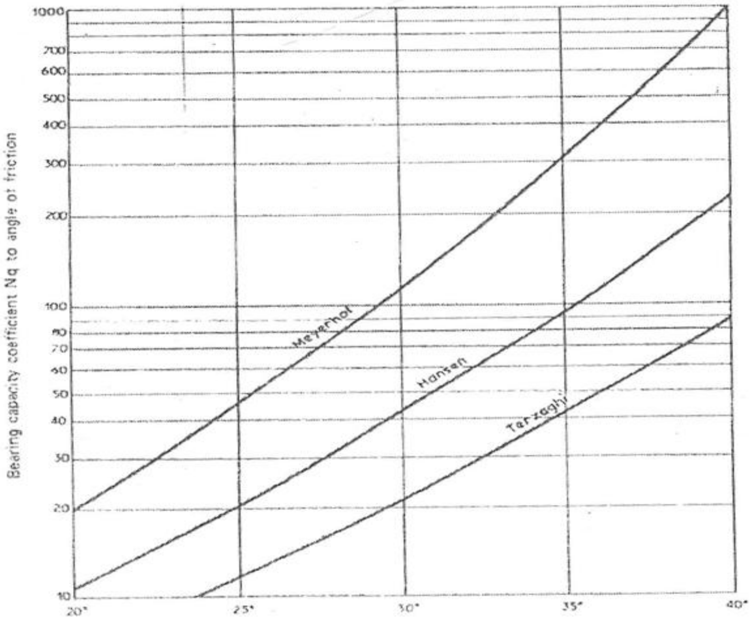

Fig. 4: N_q coefficient for deep foundation (after Pierre Le Tirant, 1979)

Total settlement:

The total settlement can be determined can by using following equation:

$$P_i = 0.6qB / E_d$$

Where,

$E_d = P_i = (0.6x2833.19x1)/14320 = 0.11m = 11cm$

4. CONCLUSION

Pilling foundation design only can be used on shoreline construction. The shoreline pile should be having a suitable diameter to resist the subsurface hazard. The best layer which pile should rest is coral reef limestone of weathering grade III. Therefore, it is strongly recommended to use pilling foundation in the intertidal zone and highly safety measures must be consider in building in lightly hazardous zones.

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